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SIMULATION MODEL

FOR RENEWAL PROGRAMMING

CRP

SAN FRANCISCO COMMUNITY RENEWAL PROGRAM

TECHNICAL PAPER NUMBER I

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SAN FRANCISCO COMMUNITY RENEWAL PROGRAM

SIMULATION MODEL

FOR RENEWAL PROGRAMMING

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Arthur D. Little, Inc.

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PREFACE

This report describes the operation of a new analytical tool for urban renewal analysis and urban renewal planning and programming--a mathematical computer simulation model, developed by Arthur D. Little, Inc. as part of the Community Renewal Program (CRP) for the City and County of San Francisco. The report is divided into two sections. Section I presents the general description of the operation of the model and is intended mainly for the nontechnical reader. This section also provides a good introduction for Section II, which outlines the operation of the model in more technical detail.

As noted in a previous publication,[1] the CRP itself is a new device in urban renewal planning and programming. In the past, local governments have typically attacked their renewal and development problems on a piecemeal, project-by-project basis, looking at only one aspect of their overall problem at a time. As a result, traditional renewal activity has often been inconclusive and/or inadequate, and, at times, even divisive in dealing with the problems created by urban blight. Through CRP, however, local governments will be able to combine many of their existing programs with some new tools and programs, and plan them in an integrated manner, on a time-phased, priority basis. It is expected that in this way, much duplication of effort and major program failures can be avoided. Furthermore, because of this combined approach, greater impact on key problems can be achieved.

The failures and weaknesses of renewal activity in the past have resulted not so much from poor planning, but from the inability of conventional methods of data analysis and forecasting to identify and measure accurately the repercussions and consequences of various public and private actions. In short, it has not been possible to allow for the fact that actions aimed at one part of the environment affect other parts, that programs aimed at physical environment often affect the social environment, and that programs aimed at one area affect other areas.

The unique advantage of the mathematical simulation model described in

[1] San Francisco Community Renewal Program (CRP): Purpose, Scope and Methodology (A progress report to the Department of City Planning), Arthur D. Little, Inc., (August 1963)

this report is that it reproduces, in an abstracted form, the actual interrelationships that occur, or might occur, in the market for land and building space in the city. The model provides an organized structure or framework for examining relationships that exist between the various elements that constitute the city's land and building space market. The relationships are represented by a set of mathematical equations. By altering the numbers and thus affecting the relationship between certain elements, we can determine the effect of various public or private decisions on the different components of the city. The availability of modern, high speed, large capacity electronic data processing computers makes feasible both the use of these techniques and the utilization of the extensive data necessary to examine fully the interactions of various elements of the city.

The CRP simulation model as initially designed will deal primarily with the residential sector for which data in the detail necessary are most available. If the model proves as useful as we anticipate, the intent is to incorporate the industrial and commercial sectors at a later time. We are currently programming the model for the computer. During the programming phase and initial testing period, some modifications, of course, may be made as they become necessary or appropriate. The model is intended to be an ongoing tool of the city--to be developed, refined, and modified in the future as conditions change.

It is anticipated that most runs of the model will consist of six time intervals of two years each, providing a twelve-year forecast. The twelve-year period was selected not for the purpose of committing the City to a program of public actions for a twelve year period but rather to make it possible to assess the long-term implications of any action that the City may undertake now or in the next few years in relation to a program of longer duration.

The simulation model has been developed to achieve several purposes:

1. To develop alternative, long range strategies and programs for renewal and development of the City, and to indicate the costs and benefits of each strategy and program

2. To serve as an ongoing tool of City government, to permit City officials to keep the CRP which emerges from our current effort up to date in light of changing conditions and/or goals, and to have available on a continuing basis a method for testing the consequences of various renewal actions before they have actually taken place

3. To identify key statistical symptomatic indicators which should

be maintained on a continuing basis so that the City can be aware of the rate and direction of changes affecting it and take appropriate responsive action.

The design of the simulation model has been a long process involving the work of both the Arthur D. Little, Inc., Operations Research staff, and planners, economists and social scientists of the Arthur D. Little, Inc. Urban and Regional Economics Section. Initial concepts as to the general use of a model in renewal programming were primarily the contribution of Dr. Ira M. Robinson, Project Director for the CRP and Dr. John W. Dyckman, Project Consultant. Mr. Martin Ernst, head of Arthur D. Little, Inc. Operations Research Section, developed the first complete statement of the model. While most of Mr. Ernst's basic operations have remained intact, numerous significant modifications and techniques have been subsequently developed in the process of translating his initial statement into a fully operational mechanism. These have come about primarily through the interaction of Dr. Robert L. Barringer, Dr. Harry B. Wolfe, Mr. Frank Hendricks, Mr. G. Thomas Kingsley, Dr. Louis Loewenstein, Mr. Harry Foden and Dr. Robinson. Drs. Barringer and Wolfe, of the OR Section, have played the key roles in this process by meshing their own ideas with those of others to construct a truly workable procedure.

I DESCRIPTION OF SIMULATION MODEL

Before describing the actual flow of operations within the simulation model, we will present an overall view of the nature and structure of the model, and explain the functions of the main "actors" which are implicit in the model.

A. NATURE AND STRUCTURE OF THE MODEL

Our simulation model is based on the premise that the need for renewal may be identified primarily with the physical aspects of the City, as these are shaped by the functioning of the real estate or "space" market of the City. It is also an axiom of this approach that those public actions which may constitute a renewal program must be evaluated and selected in relation to the functioning of this market, both to optimize this functioning and to insure certain general public welfare considerations not necessarily inherent in the functioning of the market.

The model is, in effect, a replication of the land and building space market in San Francisco. The effect of public actions and controls on the market can be evaluated by introducing into the model alternative "hypothetical" public actions and controls. Analysis of these effects provides a basis for developing a long-range strategy and program for renewal.

The operation of the model is based upon a matching within the computer of existing stocks of space in the city with the potential "users" of the space, on the basis of the relative need or desire for particular types or categories of space by particular categories of users. When the existing supply of space is not adequate to satisfy the needs of the different users, changes in the space stock are generated within the computer to a degree sufficient to satisfy this need within the limitations of the financial feasibility of the change. Financial feasibility is determined by comparing the rent-paying ability of a prospective user category with both the cost of making the change and the anticipated future yield of the change in space-type. If this comparison indicates that profitable development conditions exist, the computer will add an appropriate number of new housing units to the inventory of the City's housing stock. The computer will then compute the new conditions that would result from these additions - shifts in rent levels, new market values, modifications to

the tax base, changes in neighborhood amenities, etc. When all effects have been accounted for, new inputs are fed in and the process begins again. In this way, over a series of iteration periods, a new configuration of space-usage is repeatedly generated, approximating the actual functioning of the City's space market and the physical development of the city.

Public action programs may be introduced into the simulation as they affect the operation of the market, either by interfering with influencing, or controlling its functioning. Such actions may take the form of a zoning code which prohibits certain changes in the use of space from taking place; code enforcement and renewal projects which "artificially" introduce changes in the space-use and condition configuration, or financial measures, such as tax changes or cost subsidies, which can affect the quantity and/or quality of housing available. The resultant effect of the public actions on the allocation of space-usage may be evaluated in terms of official City policy regarding community goals and objectives. In this way proposed actions may be evaluated, and from this a continuous program of actions may be put together to achieve the objectives of renewal.

B. MAIN ELEMENTS OF MODEL

1. Housing Stock

The City's residential space will be characterized in the following manner. The entire City is to be divided into approximately 100 different Neighborhoods. Each Neighborhood will be about the size of a census tract although Neighborhood boundaries will not necessarily follow census tract boundaries. Each Neighborhood is identified by a "location category", relecting its special social pattern, land-use pattern, amenities, and transportation accessibility to downtown. For convenience in gathering data, Neighborhood boundaries will follow the boundaries of census enumeration districts.

Within Neighborhoods, the basic land unit is one which has been defined for the specific purposes of the model, called a "fract". A fract is a constant unit of land area--about three to four acres, i.e., about one large City block or two small blocks. Neighborhoods will include different numbers of fracts proportionate to their size. Each fract will be homogeneous with respect to its space type and condition; a fract cannot have mixed land use within it. Furthermore, while a given fract lies within the boundaries of its Neighborhood, a fract is not necessarily a contiguous group of parcels. Rather, a fract represents a grouping of many parcels in different parts of a Neighborhood having a common space type and condition. It follows from this that although a Neighborhood can be located geographically, a fract is located only within a given Neighborhood. Its location within

that Neighborhood cannot be pinpointed. Transitions in use of space and housing--new construction, conversions and mergers, or changes in condition of the stock--occur one fract at a time. It has been necessary to utilize the concept of the fract as the basic land unit, in order to keep the inventory of space in the City within the memory capacity of a large computer. For the purposes of this model, we have also adopted the term "building project", or "transition", which represents one or more entire fracts that undergo, or are likely to undergo, a change in their space-type and/or condition.

The residential space in each fract will be described in some detail, according to the following attributes or categories:

- Type: single family structures: 2-4 units per structure, 5 or more units per structure: or vacant land
- Number of rooms per dwelling unit
- Condition: sound, minor repair, deteriorating, or dilapidated
- Tenure: owner-occupied or rented
- Rent or value

Thus, all residential space in the City will be differentiated according to three major characteristics: (a) its space-type, including the type of housing, the number of rooms per unit, tenure, and rent (or value); (b) its condition; and (c) its location.

Associated with each fract will also be a number of ON-OFF indicator "flags" which keep track of various items of information. It is assumed for example that two different projects or transitions will not occur on the same property within the same two-year period. Thus, when a transition has occurred on a given fract we will turn one flag ON, signifying that this fract is not available for another transition in this two-year period. Flags on all fracts are turned OFF at the beginning of the next time period.

A different flag is used to signify that a fract is owned by a public agency or is permanently unavailable for transition in the market, until such time as this flag is turned OFF (exogenously).

A third flag will indicate whether a fract is available for occupancy by residential users in spite of its ownership by a public body. For example, the City may purchase property for a redevelopment project and allow households to continue to occupy the space for a few years although this land is unavailable for transition in the private market.

A fourth flag is introduced to signify a fract on which code enforcement has been applied. If this flag is ON, and the property is in substandard condition, a transition may occur during this time step to bring the property up to code. If all projects have been executed for which the yield satisfies the necessary economic criteria and this property remains in substandard condition, it then must undergo an upgrading transition even if this is uneconomic. The computer will examine all possible transitions available for this property and choose that transition whose yield is the highest, whether or not it satisfies the economic criterion.

Two other flags are exogenously controlled to signify fracts in rehabilitation or redevelopment areas. Separate cost lists are used to evaluate projects in these areas.

2. "Users" of Housing Stock

The population of San Francisco is considered to be divided into a number of different "user" categories. For residential users, the household is the basic unit. Households are categorized by:

- Household type
- Number of members in household
- Race of head
- Household income
- Occupation of head
- Rent-paying ability

The model will start with the current inventory of San Francisco population in each category, and will be provided (exogenously) with projections of the number of users in each category for each biennial period. This information on households for the start of the model (as with the information on the current inventory of the housing stock) will be developed from special cross-tabulations from the 1960 census. These population projections will reflect changing numbers of households and changing characteristics of the population. They provide the origin of the pressures which will force changes in the residential space-use pattern of San Francisco. The projections will probably take the form of a range of possibilities--both as to total population and household characteristics.

Each household or user type will have associated "preference lists" of desired housing, with respect to type and condition of housing and location category. The preference list is in order of priority so that the first space type (including location) represents the first choice of living space for a household type. The space types listed will in general be those for which the people in a particular kind of household would normally search and make their needs felt through real estate agents. In other words, a low-income household might strongly wish it could afford a Russian Hill apartment, but unless this household type would normally go to Russian Hill to inquire of the availability of this kind of apartment, Russian Hill would not be put in the preference list for this household.

Each user type will also have an associated statistical distribution of "rent-paying ability". This represents the normal range of payments that households in the particular user category can afford for rent, or for monthly payments in the case of single-family house owners.

3. Private Market Operation

Consequently, we have considered that a building project is feasible when the yield from it is sufficient to cover the amortization of the building cost plus the return normally expected of an investment opportunity with this amount of risk.

The characteristic "yields" are parameters which are rarely changed. The yield of a given project depends upon the ratio of net rental obtained for the resulting space to the cost of executing the project. The costs for a given type of project are also parameters entered into the computer. The rental obtainable for the resulting space is the current rental for the space. This is sensitive to the pressure for the space in question, where the pressure is defined as the ratio of "relevant users" to the total number of housing units available. The "relevant users" include those who desire the kind of space in question and can pay for it, and the users who are forced to accept this as a second or lower choice because they could not obtain the space they primarily desired. In occupying the space, they bid up the rental of this kind of space, and, therefore, are also considered part of the relevant users.

If the pressure is less than unity for a given type of space, then it is assumed that all households who desire this space will be able to obtain it and some of the space will still be vacant. If, however, the pressure for this space is greater than unity, then some households seeking this kind of space will be considered unable to satisfy their first choices.

It should be emphasized that the model is concerned only with that part of the market which deals with space transformations, i.e., where the physical housing is changed in some way. The model is not concerned with financial transactions where a property only changes hands. It is important to note also that the reasoning leading to the execution of building projects assumes a high degree of rationality in the operation of the real estate market. It assumes further, that the market can be predicted by focusing on the characteristics and parameters of property, rather than on the different entrepreneurs who may be involved in individual projects--such as loan officers, builders, investors, and agents. It was not possible to account for these entrepreneurial factors. Nor was it possible to account for a wide variety of factors which are either subjective, or are rational to individual developers in the light of detailed information which is unavailable to the computer, such as the particular tax status of the developer or investor.

We have attempted, however, to account for a special aspect of the real estate market, known as the "bandwagon effect". When one project is executed profitably, other developers tend to build similar kinds of space expecting similar profitability. Thus, projects are planned and the development proceeds. Meanwhile, the demand which made the initial project profitable becomes satisfied, but current plans are in such an advanced stage that builders are unwilling or unable to change them. In this way a degree of overbuilding of certain kinds of space may occur. Provision is made in the simulation model for testing the bandwagon effect, but this is the only subjective effect which is operative in the model.

It is felt that the best way of accounting for the operation of the private real estate market and thus of predicting what the City will look like in the distant future is to consider that the market operates in response to investment yields. In other words, although individual developers may have different motives and different lines of reasoning, in the long run, more projects will be executed in those areas where the yield is larger.

If our model were designed to predict the form of the City after a period of two to four years, it might be structured differently; for example, it would weight heavily current trends in building. We feel that our yield computations will provide more accurate results over a period of eight to twelve years, which is the design horizon for this simulation model.

4. Public Actions

As noted in the Preface, the primary purpose of the model is to test alternative public programs for the City and County of San Francisco. The process for testing alternative policies and programs will operate roughly as follows: 1) a hypothetical series of alternative programs, each including

a different strategy for urban renewal, public housing, code enforcement and many other activities--will be developed exogenously; 2) these will then be expressed in model terms and entered directly into the computer; 3) the model will then go through its normal operation, forecasting future changes in the City's space use system, but, based on the specific set of conditions implied by the public programs. That is, the public programs will have changed conditions in the model, thus changing the basis for forecasting. The model will therefore identify the probable effects of the various alternative programs: e.g., the amount of additional housing produced, changes in the tax base, new rehabilitation, modifications of rents, etc.

In order to translate programs for model use, it has been necessary to define them in terms of a specific set of "public actions" which can make direct changes in the accounts in the model. Urban Renewal, for example, is made up of a series of actions, such as purchase land, demolish structures, improve the site, offer special financing, etc. Each of these can be measured and entered into the computer.

For model operation, public actions can be divided into three basic types. The first type involves actions which change the value of any of the so-called fixed parameters in the model's structure; e.g., the zoning matrix or the schedule of rent-paying abilities. The second type involves the direct changing of space-use type, condition, or flag configuration of fracts. The following items can be specified in this type of action: the number of fracts, the Neighborhood in which the change is to take place, the old space-use type and condition, the old flag configuration, the new space-use type and condition, and the new flag configuration. The third type is code enforcement. Code enforcement is applied on a given fraction of the buildings in the area as designated. Those found to be "substandard" are either brought up to "standard" condition or replaced with a new building, whichever yields the best rate of return.

The following are examples of some of the possibilities for using the first two types of public actions. Type 1 can include the following:

- Restrict private occupancy changes: Anti-discrimination ordinances can be taken into account by a change in the preference list for minority group households. If minority groups are restricted against moving into an area, then the locational category corresponding to that area will not appear in their preference listings. An anti-discrimination ordinance can be reflected in the model by inserting locations into the preference listing which before were not represented.

- Tax rate and assessment: The general level of taxes can be reflected in the yield values against which individual projects are compared.

- Cash subsidies: Subsidies will change the rent-paying ability of certain classes of households.

- Rent control: The rental which may be charged for a given class of residential units is limited to a stated maximum.

- Mortgage and loan insurance: This type of aid for investors may reduce the minimum yield required by an investor for a particular kind of project.

- Direct reduction of cost of financing: In this case also the minimum yield required for the execution of a project is reduced.

The following items are included in the second type, which involves direct change in the space-usage or condition of housing structures.

- Purchase property: This is carried out by changing a "flag" and does not require an actual change in the space-use type.

- Sell property to private sector: The City can encourage the use of land for specific housing type by selling land to a developer at a lower than market price.

- Maintain or upgrade property: The condition of property owned by the government is maintained or upgraded.

- Demolish building: The space-use category is changed to a category called "Vacant".

- Site improvements: The space-usage is changed from "Vacant" to "Vacant - Improved".

- Construct buildings for public or private use: The space-use can be changed to reflect the construction of a new building. By means of the flags we can specify whether this building is for private use, or for public housing with the consequent occupancy by household units, or for general public use as in the case of public facilities.

- Lease property to private sector: Public housing can be leased to households at a rent established by the government. This may be below the normal private market rent; this action therefore has an effect similar to the rent-control option.

These, along with code enforcement and some others, represent a basic "alphabet" of public actions. They can be combined in various groupings and over time to form abstractions of real programs for urban renewal, conservation, and so forth.

5. Public Financial Accounting

One of the key elements in the process of evaluating various public programs and model outputs is an examination of their fiscal implications. The model, therefore, presents a forecast of future public expenditures and revenues for each separate model run. This is accomplished essentially in the following way:

(1) Estimated unit cost factors are applied to each public action in the run to forecast future expenditures in these areas

(2) Separate methods are used to forecast future expenditures for other public activities which are not programmed in the model

(3) These are summed to provide an estimate of total future expenditures

(4) Various non-property tax revenues are estimated

(5) Property tax revenue is computed as a residual and related to the model's estimates of property values to establish future tax rates

(6) Bond redemption and interest implications are abstracted.

C. MODEL OPERATIONS

The description of the model presented in this section is intended mainly for the nontechnical reader. Section III of this report describes the flow charts and technical aspects in greater detail.

The nine major steps of the simulation program as outlined in Figure 1 are discussed below. As mentioned in the Preface, it is anticipated that most runs will consist of six time intervals of two years each, giving a 12-year forecast. During each of the time intervals, the major part of the program, represented by Steps 2-8, is repeated.

Step 1

In Step 1, the various counters are reset or initiated, and starting inventories of household users and space are set. For example, if the simulation begins in 1960, then the inventories existing in 1960 would be inserted into the program at this stage.

Step 2

In each time interval, the first step in the computer program is concerned with a number of tasks associated with the passage of time. The most important of these tasks is "aging" of the space stock. Although only a small portion of the total stock of the City is substandard, it is nevertheless important to trace this stock, as it can largely determine the desirability of different Neighborhoods and the kind and amount of public actions required to improve the housing supply. Therefore, for each time period, the condition of a small portion of all housing units is aged probabilistically to a lower condition. The portion of units that age or deteriorate will vary from Neighborhood to Neighborhood, reflecting better or worse maintenance.

Spontaneous transitions may also be made to a better condition. These reflect repairs made on a unit to improve its condition when these are motivated not by economic considerations but by an effort to maintain the structure. Housing units frequently are maintained or improved not in the hope of obtaining an immediate increase in rentals to offset the cost of maintenance, but rather to maintain the property in the long run. This is particularly true of owner-occupied units.

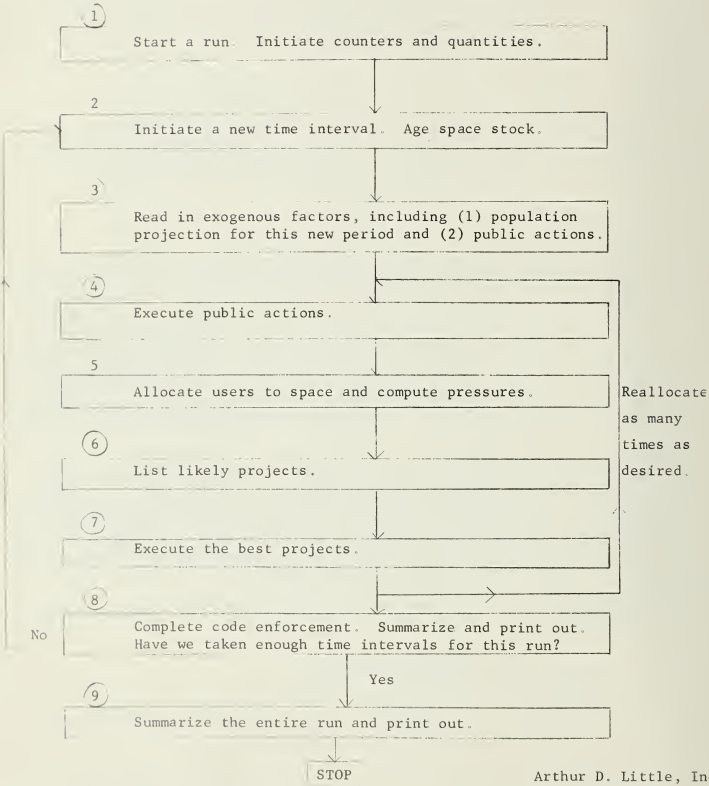
The aging operation is discussed in greater depth in a separate technical memorandum.

Step 3 - Read in Exogenous Factors

The exogenous factors to be read into the computer will include a projection of the number of households in each individual category for the

Figure 1

ABBREVIATED FLOW CHART



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current time period, and a list and operational description of public programs to be implemented during this two-year period. As discussed above, there are a large number of different individual public actions that can be handled in the model. Using alternative groups, packages, or "bundles" of these individual public actions, all the important public programs affecting land usage currently in use can be tested. In addition, by regrouping the individual actions, types of public action can be simulated which may not be used now but which can be tested for their effectiveness.

Step 4 - Execute Public Action

The public-action bundles are implemented, through the mechanisms discussed in the section on Public Actions, above. This includes either changing parameters, such as Neighborhood zoning, or changing the "flag" designations of individual tracts or Neighborhoods.

Step 5 - User Allocation

In order to compute the number of relevant users it is necessary to carry out a rough allocation of the households into the residential space stock in San Francisco. The purpose of the allocation procedures is primarily to compute the pressures. Thus, we have designed a method that gives partial information on which household group occupies which housing type, but does not provide information on the length of tenure of a particular family in a particular housing unit.

The allocation procedure makes use of the preference lists of the desired space types for each of the household types. Briefly described, the allocation method proceeds as follows.

(a) Choose the user category best able to compete for space. This will depend on such factors as income, race, and children; the assumption being the higher income households, non-Negro races, and families without children are generally in a better position to compete for the type of housing they most desire.

(b) Check whether any of their first preference space is available, and whether these households can afford the rental or cost. Place the members of this household group into the available space.

(c) If that space is already filled by those better able to compete for it, or rental is too high, repeat Step (c) with the next lower preference space. Tally the number of "relevant users".

(d) Continue down the list of household types, allocating each household type into its highest preference space that is both available and within reach of its rent-paying ability. Add the number of relevant users to the tally for each space type.

(e) There may be more members in a household category than will fit into any of the unallocated space in its preference list. In this case, the computer will assume that either (1) these households leave the City (if they are in a category with mobility and flexibility to do so) or (2) they are forced to accept overcrowded conditions (if they are in a user category that does not have the means to go to the suburbs). Tallies will be kept of the number of families in both these circumstances.

When the allocation procedure is finished, the computer has a tally of relevant users for each space type (including location). This information of the user groups allocated to each space type is used in two instances. The first is for the print-out, which can summarize the number of each user group allocated to the different space types and Neighborhoods.

The second is for consideration of code enforcement or rehabilitation of substandard units. For this purpose, a count is kept of how many of the households inhabiting substandard dwellings could afford to rent the same units if they were brought up to standard (or up to code) with the resulting increase in rental. The number of households that would have been able to afford the corresponding standard units is determined by comparing the rent-paying ability for each user group, and the rental per unit. The rental asked for units of various types, sizes, and conditions are those computed from previous steps.

For each space type (including location) the computer calculates the ratio between the total number of relevant users and number of available housing units in the City. These ratios are the values of "pressure" for each space type. For those space types where this economic pressure is less than unity, a vacancy factor can be computed.

If the pressure for a given kind of space is equal to unity, then the rental equals normal rental. However, if the pressure is greater than unity, then the rental is (temporarily) greater than the normal rental. If the pressure is less, then the rental is less than the normal rental. This mechanism reflects the response of rents to demand for space.

The computer also tallies the users who desire each kind of space as their first choice. In an ideal City, every household would have its first choice available to it. If we take the ratio of these first priority users to the number of available units, we obtain a kind of pressure for adaptation, or "adaptive pressure". This then becomes one standard of comparison to judge how well the City performs its housing function. Thus, adaptive pressure is a number used in making decisions relating to public actions. In the same way that the private developers take action in response to economic pressure, public actions can be seen as attempting to relieve adaptive pressure.

Step 6 - List Likely Projects

When the pressures have been used to compute rental for each space type, the computer can set out a list of likely building projects in the City. This is done in the following manner:

(a) Choose the space type with the highest economic pressure. Search throughout the City for, first, a Neighborhood which is zoned for this kind of space, second, a fract within this Neighborhood which can be transformed to the space type in demand.

(b) Compute the yield for this project from the pressure and rental for the space type in demand, the pressure and rental for the current type of space, and the cost of the transformation.

There might be a large number of different fracts which can be converted to the type of space desired. Some of these projects may have yields which are less than the standard yield for this project and thus are not economically feasible. Of those for which the yield is greater than the standard yield for this kind of project, the ones with the highest yield will be identified and put into a list of potential projects. These projects are not executed immediately for reasons to be explained below.

The list of potential projects is built up by identifying the space type with the second highest pressure, third highest pressure, and so forth, and placing in the list projects for each space type with sufficient yield. The number of projects to be placed on the list of potential projects will depend on the difference between demand and the total available space in the City. For a popular type of building (e.g., high-rise apartment house) the "bandwagon effect" can be simulated by placing in the list more projects than are sufficient to satisfy the current demand.

We do not execute projects and perform space transformations as soon as they are identified since there is no assurance that the project with the highest yield corresponds to the space type with the highest pressure. It is likely, however, that the project with the highest yield will correspond to a space type with high pressure, as this kind of space type will command a rental figure which is high compared with its normal rental.

Step 7 - Execute Projects

The project execution phase uses the list of potential projects built up in the previous step. The potential projects are executed in order of yield up to a given maximum number per cycle, or as long as the yield remains above the minimum yield expected of the project. After a given maximum number of projects have been executed, the model can recycle

through Steps 5-7 This will represent a reallocation of users and recalculation of pressures and rents, taking into account the projects just executed in the current two-year interval This recycling and recalculation will prevent overbuilding in any interval, when the number of projects already executed is sufficient to satisfy at least part of the pressure The rents and yields may, as a result, decrease to the point where further construction of a particular space type is no longer attractive The degree of bandwagon effect, or overbuilding, can be simulated by varying the maximum number of projects executed in any cycle There may be several such cycles in any two-year time interval

When there are no more projects whose yields satisfy the requirements, the computer is ready to summarize the statistics and to proceed to the next time interval

Step 8 - Print Out Interval Data

We are developing a wide variety of different possible output options, which will print out statistics relevant to the two-year time interval. The purpose of the run will determine the output options desired. Thus, if we are testing a public action designed to alleviate overcrowding in the City, we would want to have a fairly detailed view of which user groups are forced to accept overcrowded conditions. On the other hand, if we wish to test the results of a stronger anti-discrimination ordinance, we may want to know the distribution of Negro households and the yields in certain Neighborhoods During some runs it may be desirable to sum the market value of all property within the City limits in private ownership to make an estimate of the total tax base. A different kind of study might be concerned with the amounts and location of substandard housing. For this run we would want summaries of Neighborhoods containing large amount of substandard housing. As a final example, the run may be more concerned with the total building activity in the City, both in new building and in rehabilitation, as this responds to various public action programs Other examples of output options include the following

- Summary of new construction by space type and fract
- Summary of rehabilitated units by space type and fract
- Total cost of private construction
- Total cost of public construction
- Total cost of public expenditures
- Space types with economic pressure greater than unity
- Space types with adaptive pressure greater than unity
- Households not finding any space in their preference list, or forced to leave the City

After the print-out step, the model repeats Steps 2-8 for the next two-year time interval.

Step 9

When the program has proceeded as above through six time steps representing twelve years, there are special print-outs at the end of the run summarizing the twelve-year history. In addition, statistics on trends in the City during the twelve-year period are printed The computer program is set up so that the computer need not stop at the end of one complete run, but can immediately start on another run if several runs are desired in one series.

II. SIMULATION MODEL FLOW CHARTS

In this section the simulation model operations are discussed in greater detail than in the preceding section. Detailed flow charts are presented in the Exhibits. The nomenclature and some of the relationships and numerical tables implicit in the flow charts are discussed below.

A. HOUSING STOCK

T. The Tract or Neighborhood under consideration. As mentioned in Section I, each Neighborhood will be about the size of a Census Tract. In some cases Census Tracts will be broken into two or more areas to form a Neighborhood, and in other cases similar Census Tracts will be grouped together. In all cases, T will refer to the Neighborhood involved whether or not it corresponds exactly to the Bureau of the Census Census Tract.

L. A vector describing Neighborhood locational characteristics, including social pattern, amenities, and accessibility. Several Neighborhoods, in different parts of the City, may have the same L locational vector.

j: j refers to type of structure, independent of condition.

jc: jc refers to type of structure including the condition of structure.

The use of a prime, such as j' or c', will refer to a different space type or a different condition. This may correspond to a space type falling to a lower condition category through aging or to an actual physical change in the space type due to execution of a "project": new construction, conversion, rehabilitation

Ccc': The cost required to change the condition of structures in one fract from condition c to condition c'.

Cjcj'c': The cost required to change both condition and type of the structures in one fract.

MjcT: The total number of fracts available of space type jc in Neighborhood T.

M'jcT: The number of unallocated jc fracts in Neighborhood T.

MjcL: The total number of available fracts of space type jcL in the City. MjcL is equal to the sum of MjcT over all Neighborhoods with the same L locational vector.

M'jcL: The total number of unallocated jcL fracts in the City.

QljcT: The number of fracts of type jc in Neighborhood T that have first preference in households' preference listings.

Q2jcT: The number of fracts of type jc in Neighborhood T for which "relevant" households have a preference. If MjcT is not completely filled, "relevant" households are those that are allocated to jcT. If MjcT is filled up, then to these households are added those that would have been allocated to jcT if it were not filled. All "relevant" users must have sufficient rent-paying ability to afford the current rent for the units.

QljcL: The total number of fracts of type jcL that have first preference in households' preference listings. QljcL is the sum of QljcT over Neighborhoods with the same L category.

Q2jcL: The number of fracts of type jcL for which relevant households have a preference.

VjcL: Vacancy rate for type jcL space (when M'jcL 0)

$$VjcL = M'jcL/MjcL$$

PljcL: Adaptive Pressure for jcL type space.

$$PljcL = QljcL/MjcL$$

P2jcL: Economic Pressure for jcL type space.

$$P2jcL = Q2jcL/MjcL$$

RjcL: The rental obtained for a jcL type of fract.

$\bar{R}$jcL: The normal rental obtained for a jcL type of fract (when economic pressure is near unity). We postulate a linear rent-pressure relationship:

$$RjcL = \bar{R}jcL + \bar{S}jcL\ (P2jcL - 1), \text{ where}$$

$\bar{S}$jcL is the rent-pressure gradient for space type jcL, and P2jcL is the economic pressure for jcL

Rj'c'L: The rental to be obtained for a new or rehabilitated space type fract, j'c'.

YjcL: The current "brokers" yield on jcL type space, in % per year.

$$YjcL = \frac{\text{Rental Income}}{\text{Total Property Cost}}$$

Yminj: The minimum yield required for construction of new j-type building.

$$Yminj = \frac{\text{Income}}{\text{Property cost + demolition cost + construction cost}}$$

Yjcj'c': The yield for a project which changes space type jc into type j'c' (conversion or merger)

$$Yjcj'c' = \frac{R'jcL - RjcL}{Cjcj'c'}$$

YR: YR is the yield ratio, that is, the ratio of the yield for a particular project to the minimum yield for which this project is likely to be performed.

$$YR = \frac{Yjcj'c'}{Yminj'}$$

We assume that $YR > 1$ for a project to be economically feasible.

B. HOUSEHOLDS

i refers to a residential household or "user" type (categorized by income, race, occupation, and family type)

Ni refers to the total number of households of type i.

The simplest way of handling the rent-paying ability of a user group would be to assume that all users in this group cluster around a "mean rent-paying ability"; this would then identify a significant group of users at a single value. However, if the space is also assumed to have single value of rental at a given time, and this rental rate varies even slightly with pressure or time, we may have a serious difficulty. For with a very slight shift upward in the amount of rental, a large group of users may suddenly find they cannot afford this kind of space. This would mean a severe drop in the pressure for this space. To avoid this discontinuity, we distribute the rent-paying ability for each class of users.

Nik is a subset of Ni with a given rent-paying ability. We anticipate having about 20 subsets, in which case k = 1, 2, ...20. Thus,

$$\sum_{k=1}^{20} Nik = Ni$$

Although the model can handle any distribution, for present computational purposes we will approximate the rent-paying ability distribution by a normal (Gaussian) distribution over a discrete set of equally spaced rent-paying abilities between a given minimum and maximum rent-paying ability.

A given space type has a current rental associated with it, depending on location and pressure. Assume this space is desired by the users in a particular category. If the actual rental falls just above the rental which group Ni17 can afford, then only groups Ni18, Ni19, and Ni20 will be able to compete for this space. We assume that all users in an Nik group who can afford the space compete for it equally. Thus, if the space available will house, in this example, three quarters of the sum of Ni18 plus Ni19 plus Ni20, then three quarters of Ni18 would be allocated to this space, three quarters of Ni19 and three quarters of Ni20.

Similarly, if there are several Neighborhoods sharing the same Location vector that have jcL space available, then households are assumed allocated among the Neighborhoods in proportion to the available jcL space in each.

C. PROJECT LIMITATION PARAMETERS

A quantity, BjcL, is computed which represents the maximum number of space type j that can be constructed in Neighborhoods characterized by location vector L. This quantity depends on the apparent "need" for this space type, as measured by (Q2jcL - MjcL). The value may be greater or less than this "need." For the space types where the "band-wagon effect" is expected to be important, BjcL can be set greater than (Q2jcL - MjcL) to reflect this factor.

D is a parameter which determines the total number of projects which can be executed before reallocation and recomputing pressures. It corresponds to the speed of response of developers to changing market conditions.

D. DATA TABLES

The computer will have a number of stored data or numerical tables. These will include the following.

(1) The Preference Table

This table will contain a list of space types with condition, location, and desired land area. For each user group, the list will include first priority jcL space, second priority, third priority, etc. Associated

with the last priority jcL space is a notation as to whether this group will leave the City if not enough space is available for its normal desires in all priorities, or whether it will be forced to accept overcrowded conditions.

Each entry includes the desired land area, AijcL, expressed as percentage of a fract. This factor is used in the following kinds of transformations:

(a) If Ni is a number of households or users, then AijcL Ni is amount of land area desired, in fracts.

(b) If MjcT is number of fracts available, then MjcT/AijcL is number of units available.

(2) The Zoning Table

This table will contain a column for each Neighborhood and a row for each j type. The contents of a cell (a particular j type in a particular Neighborhood) will contain an indication of whether this j type is allowed or disallowed by zoning or any other ordinance. As an addendum to the main table we may include subsidiary information such as the "sum of land areas devoted to types 13, 14, and 15 shall not exceed 30% of the Neighborhood."

(3) The Location Table

This table will contain a column for each Neighborhood and a row for each element of the location category L. The contents of each cell is normally either 1 or 0, indicating whether this Neighborhood has this location element. Different elements will be of interest to different users. Those who can afford good housing will be concerned with amenities; another class of users will be interested in accessibility and commuting facilities; potential industrial users may be concerned with accessibility to docking or railroad transportation.

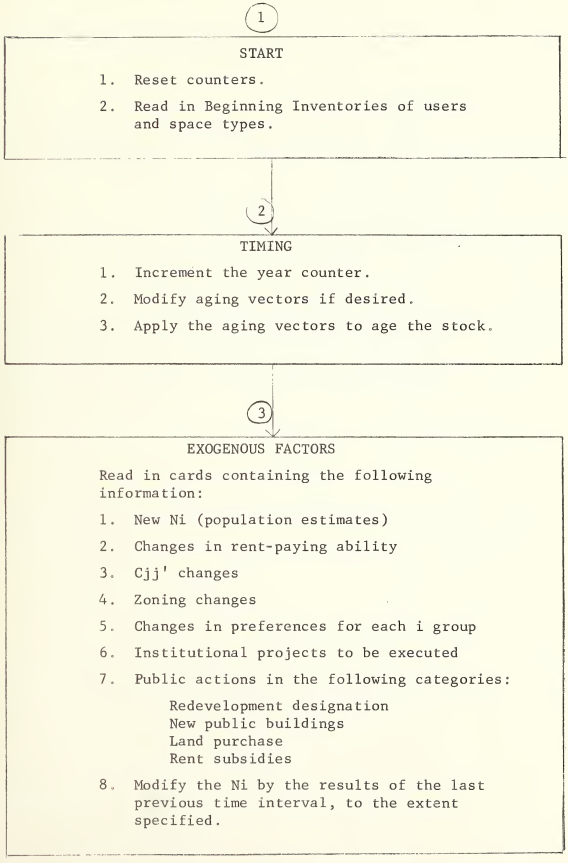
(4) The Aging Probability Table

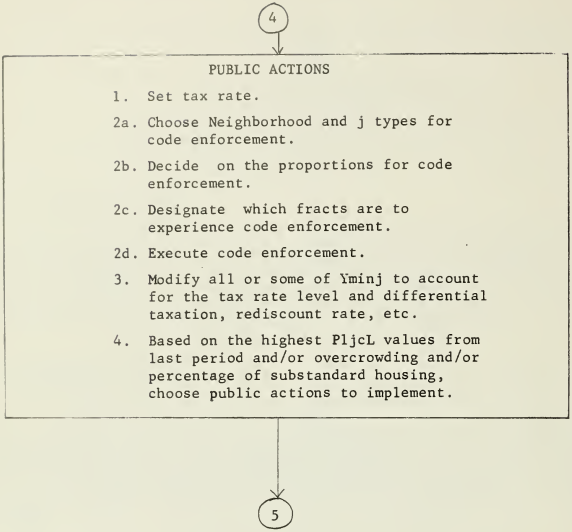
For each space type and condition (jcL) there is associated a "condition aging vector." This represents the probability that in a two-year time interval, a structure will remain in the same condition, deteriorate to a lower condition state, or be demolished. The same condition aging vector may apply to several jcL types.

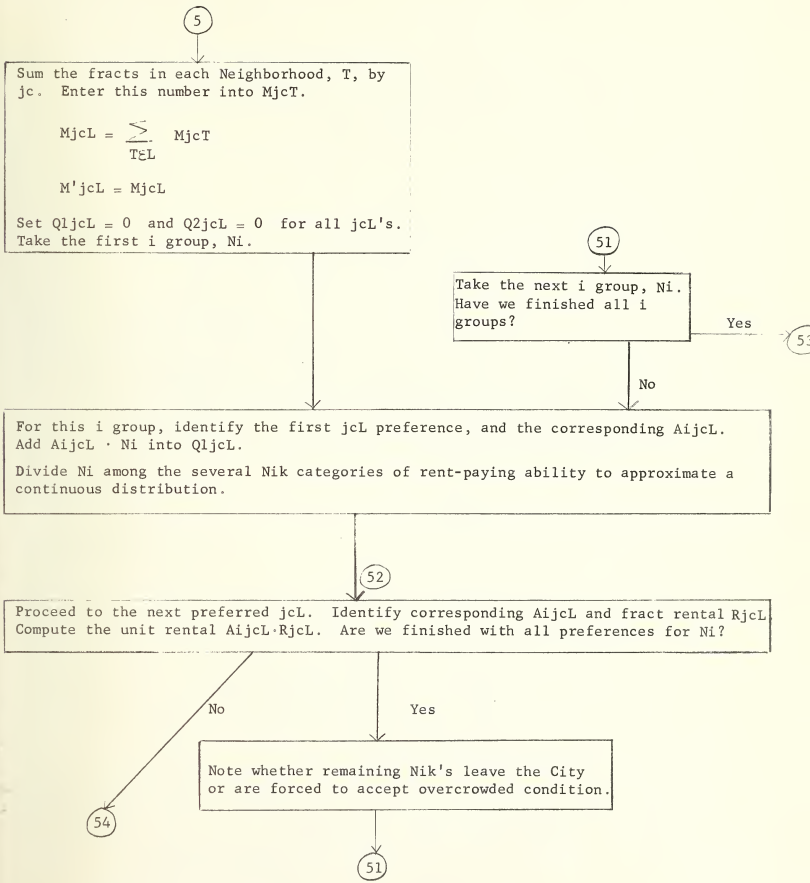
(5) The Yield Table

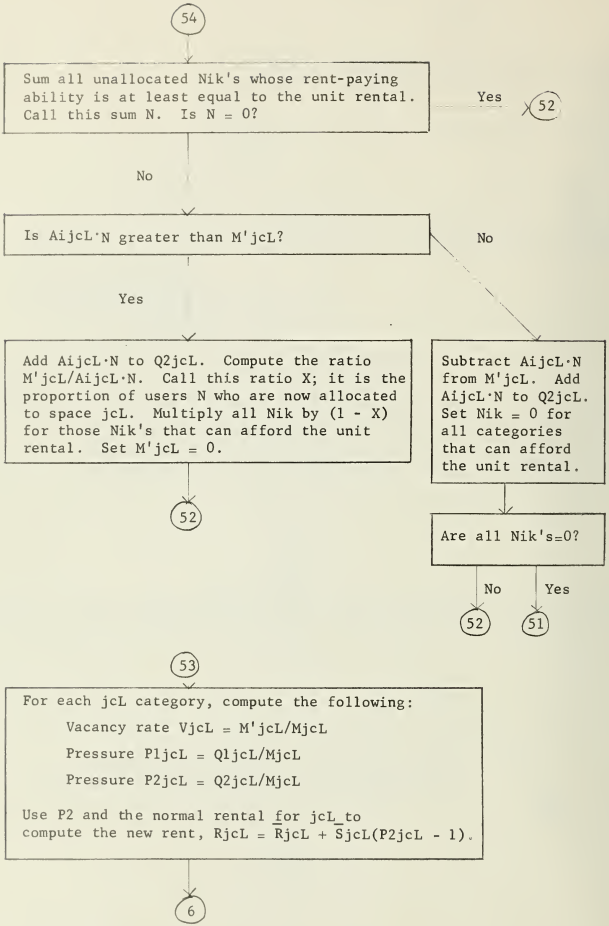
For each space type there is listed the normal, or minimum, desirable yield (Yminjc) required for this space type.

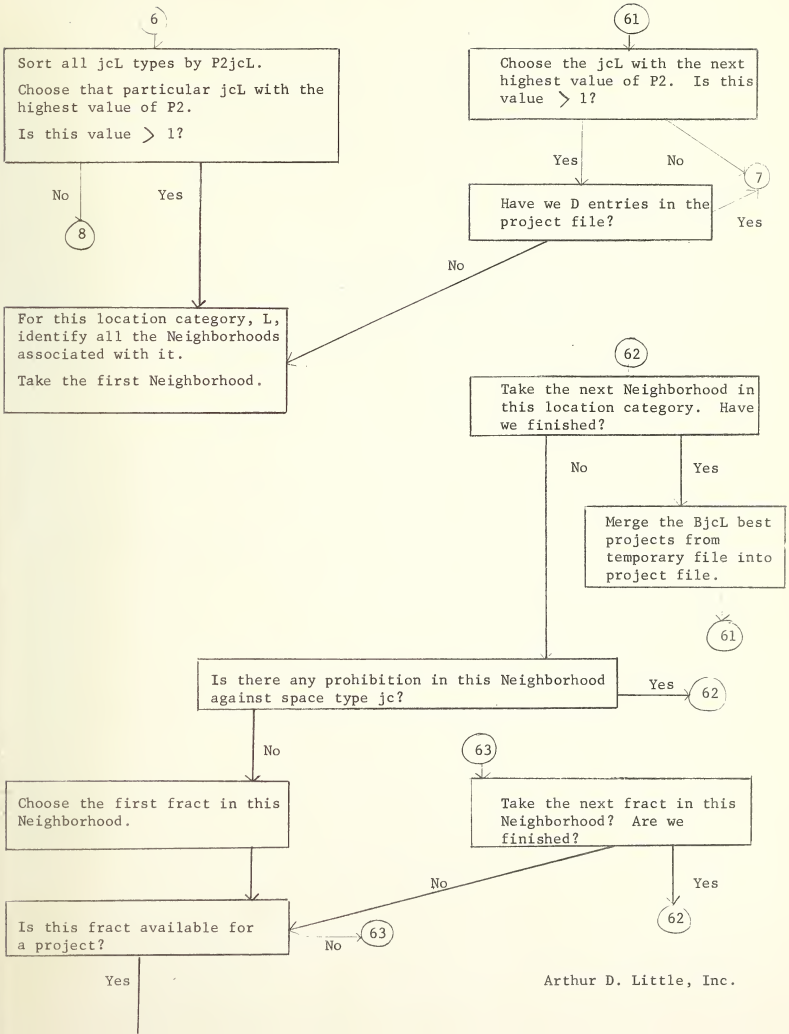
FLOW CHART

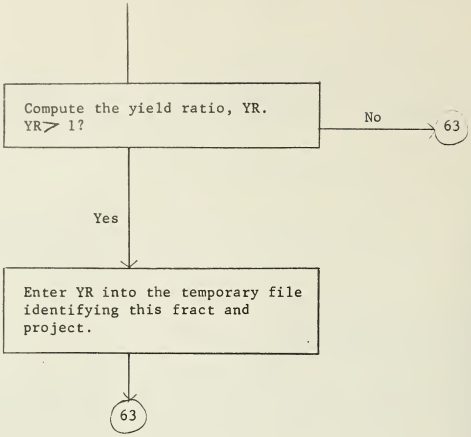

1
START
1. Reset counters.
2. Read in Beginning Inventories of users and space types.
2
TIMING
1. Increment the year counter.
2. Modify aging vectors if desired.
3. Apply the aging vectors to age the stock.
3
EXOGENOUS FACTORS
Read in cards containing the following information:
1. New Ni (population estimates)
2. Changes in rent-paying ability
3. Cjj' changes
4. Zoning changes
5. Changes in preferences for each i group
6. Institutional projects to be executed
7. Public actions in the following categories:
Redevelopment designation
New public buildings
Land purchase
Rent subsidies
8. Modify the Ni by the results of the last previous time interval, to the extent specified.
4

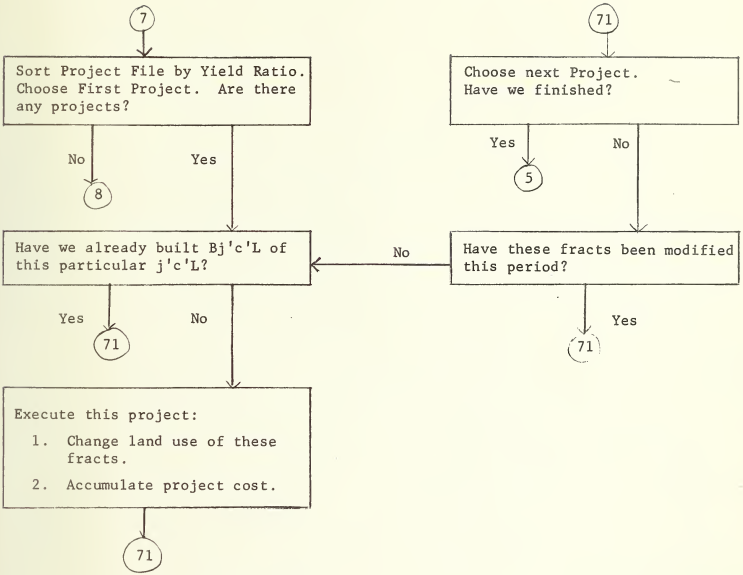

4
PUBLIC ACTIONS
1. Set tax rate.
2a. Choose Neighborhood and j types for code enforcement.
2b. Decide on the proportions for code enforcement.
2c. Designate which fracts are to experience code enforcement.
2d. Execute code enforcement.
3. Modify all or some of Yminj to account for the tax rate level and differential taxation, rediscount rate, etc.
4. Based on the highest PljcL values from last period and/or overcrowding and/or percentage of substandard housing, choose public actions to implement.
5

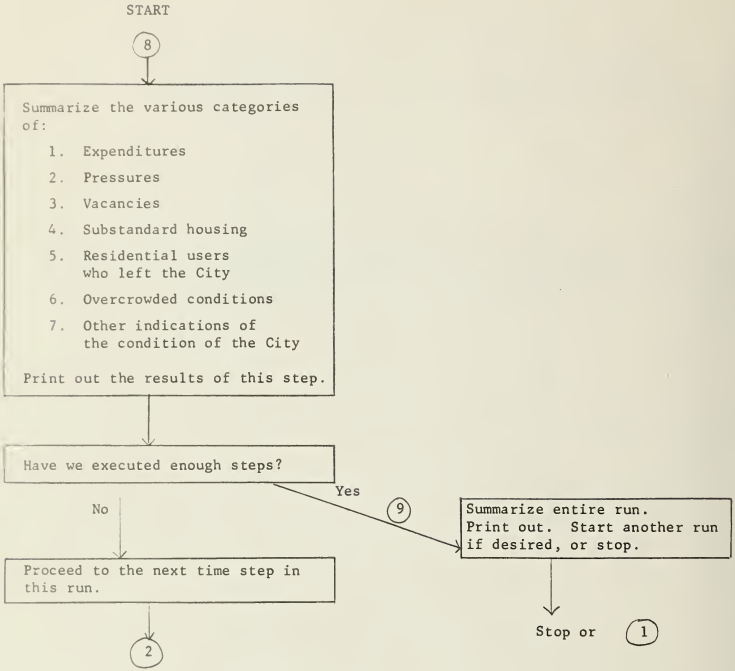

5
Sum the fracts in each Neighborhood, T, by jc. Enter this number into MjcT.
MjcL = Σ MjcT, T∈L
M'jcL = MjcL
Set QljcL = 0 and Q2jcL = 0 for all jcL's.
Take the first i group, Ni.
51
Take the next i group, Ni. Have we finished all i groups?
Yes
No
For this i group, identify the first jcL preference, and the corresponding AijcL. Add AijcL · Ni into QljcL.
Divide Ni among the several Nik categories of rent-paying ability to approximate a continuous distribution.
52
Proceed to the next preferred jcL. Identify corresponding AijcL and fract rental RjcL. Compute the unit rental AijcL·RjcL. Are we finished with all preferences for Ni?
No
Yes
Note whether remaining Nik's leave the City or are forced to accept overcrowded condition.
54
51


54
Sum all unallocated Nik's whose rent-paying ability is at least equal to the unit rental. Call this sum N. Is N = 0?
Yes
52
No
Is AijcL·N greater than M'jcL?
No
Yes
Add AijcL·N to Q2jcL. Compute the ratio M'jcL/AijcL·N. Call this ratio X; it is the proportion of users N who are now allocated to space jcL. Multiply all Nik by (1 - X) for those Nik's that can afford the unit rental. Set M'jcL = 0.
Subtract AijcL·N from M'jcL. Add AijcL·N to Q2jcL. Set Nik = 0 for all categories that can afford the unit rental.
52
Are all Nik's=0?
No
Yes
52
51
53
For each jcL category, compute the following:
Vacancy rate VjcL = M'jcL/MjcL
Pressure P1jcL = Q1jcL/MjcL
Pressure P2jcL = Q2jcL/MjcL
Use P2 and the normal rental for jcL to compute the new rent, RjcL = RjcL + SjcL(P2jcL - 1).
6


6
Sort all jcL types by P2jcL.
Choose that particular jcL with the highest value of P2.
Is this value > 1?
No
Yes
8
61
Choose the jcL with the next highest value of P2. Is this value > 1?
Yes
No
7
Have we D entries in the project file?
Yes
No
For this location category, L, identify all the Neighborhoods associated with it.
Take the first Neighborhood.
62
Take the next Neighborhood in this location category. Have we finished?
No
Yes
Merge the BjcL best projects from temporary file into project file.
61
Is there any prohibition in this Neighborhood against space type jc?
Yes
62
No
63
Choose the first fract in this Neighborhood.
Take the next fract in this Neighborhood? Are we finished?
No
Yes
62
Is this fract available for a project?
No
63
Yes


Compute the yield ratio, YR.
YR > 1?
No
63
Yes
Enter YR into the temporary file identifying this fract and project.
63


7
Sort Project File by Yield Ratio. Choose First Project. Are there any projects?
No
Yes
8
Have we already built Bj'c'L of this particular j'c'L?
Yes
No
71
Execute this project:
1. Change land use of these fracts.
2. Accumulate project cost.
71
71
Choose next Project. Have we finished?
Yes
No
5
No
Have these fracts been modified this period?
Yes
71


START
8
Summarize the various categories of:
1. Expenditures
2. Pressures
3. Vacancies
4. Substandard housing
5. Residential users who left the City
6. Overcrowded conditions
7. Other indications of the condition of the City
Print out the results of this step.
Have we executed enough steps?
Yes
9
Summarize entire run. Print out. Start another run if desired, or stop.
Stop or
1
No
Proceed to the next time step in this run.
2